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*American Competitiveness Institute*

**JGPP / JCAA LEAD FREE SOLDERING PROGRAM**

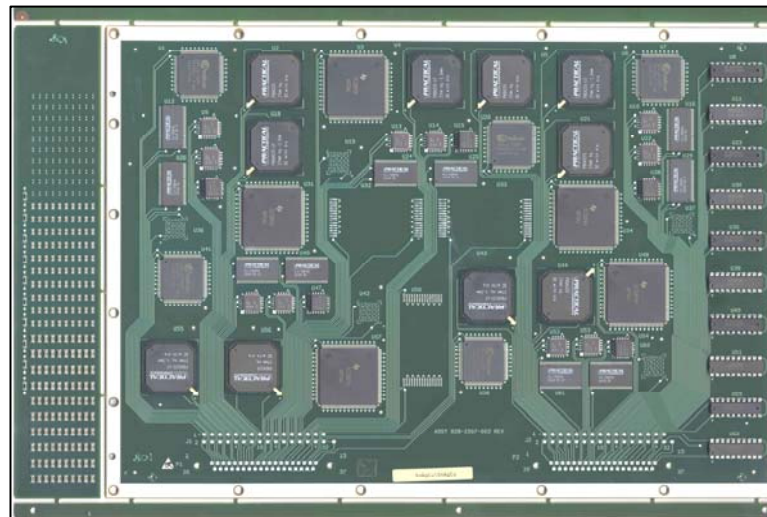
**Salt Atmosphere, Temperature Humidity, and  
Mechanical Shock Testing Results**

**February 9, 2006**

# JG-PP / JCAA ACI Environmental Testing

## Agenda

- Salt Atmosphere
- Temperature Humidity
- Mechanical Shock Test - I
- Mechanical Shock Test – II
- Conclusions



# JG-PP / JCAA Salt Atmosphere Testing

## - Test Procedure

- **Boards Tested**
  - *SnPb Boards: Serial Numbers 35, 36, 37*
  - *SnAgCu Boards: Serial Numbers 104, 105, 106*
  - *SnAgCuBi Boards: Serial Numbers 143, 144, 145*
- **Based on ASTM B117 Test Method for 48 hours**
  - *35 °C ambient with 15 psi pressure*
  - *5% salt aqueous solution*
  - *Checked continuity on all packages*
  - *Found some continuity failures prior to the test*
  - *Visual inspection for corrosive residue*



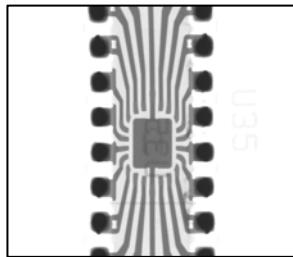
Salt Atmosphere Testing Chamber



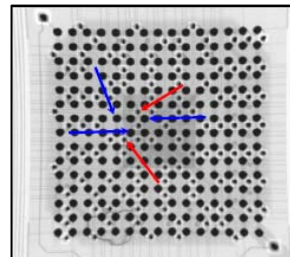
# JG-PP / JCAA Salt Atmosphere Testing

## - Test Results

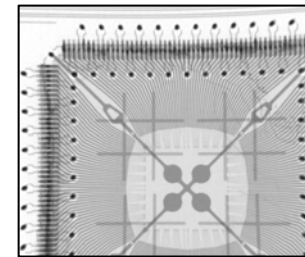
- **All Passed Salt Atmosphere Testing**
  - *Found no failures after test*
- **Failures Found Prior To Testing**
  - *Board 104: Component U35: Open Circuit*
  - *Board 104: Component U56: Open Circuit*
  - *Board 105: Component U3: Improper Wired Circuit*



Board 104  
Component U35



Board 104  
Component U56



Board 105  
Component U3



# JG-PP / JCAA Temperature Humidity Testing

## - Test Procedure

- **Boards Tested**
  - *SnPb Boards: Serial Numbers 38, 39, 40*
  - *SnAgCu Boards: Serial Numbers 107, 108, 109*
  - *SnAgCuBi Boards: Serial Numbers 146, 147, 148*
- **Based on MIL-STD 810F; Test Method 507.4**
  - *Checked continuity on all packages*
  - *Found some failures prior to the test*
  - *Visual inspection*

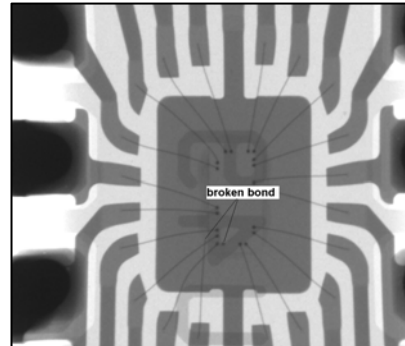
Temperature Humidity Testing Chamber



# JG-PP / JCAA Temperature Humidity Testing

## - Test Results

- **All Passed Temperature Humidity Testing**
  - *Found no failures after test*
- **Failures Found Prior To Testing**
  - *Board 38: Component U49: Open Circuit*
    - *Broken Wire Bond*
  - *Board 108: Component U44: Open Circuit*



Board 38  
Component U49





# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I

- **Mechanical Shock – I Test Procedure**

- *MIL-STD 810F; Method 516.5; Procedure 1*
- *Hardware tested in X, Y, and Z axes*
- *Crash hazard Test for flight equipment*

- **Boards Tested**

- *SnPb Boards: Serial Numbers 26, 27, 62, 63*
- *SnAgCu Boards: Serial Numbers 95, 96, 151, 168*
- *SnAgCuBi Boards: Serial Numbers 134, 135, 196, 197*



# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I

### Mechanical Shock – I Test Procedure

Step	Test	Initial G	Slope	Peak G	Ts (ms)	Cross-Over Freq.	Z-axis (thru-thickness)	X-axis	Y-axis	Total Shock
1.1	Functional test for flight equipment	4.5	6	20	15-23	45	3	3	3	9
1.2	Functional test for ground equipment	8.5	6	40	15-23	45	3	3	3	9
1.3	Crash Hazard test for flight equipment	9	6	75	8-13	80	3	3	3	9
1.4	Crash Hazard test for flight equipment	9	6	75	8-13	80	100	100	100	300

Hardware Tested In X, Y, And Z Axes





# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I

- **Continuity Testing**
  - *Performed before and after each round of tests*
  - *Confirmed failures from Event Detectors*
  - *Determine intermittent failures*
- **Hardware Monitoring: Anatech Event Detector**
  - *Continuous monitoring during testing*
  - *Detect electrical interruption lasting greater than 0.2  $\mu$ sec*
  - *Detect continuity interruption  $\geq 300 \Omega$  up to 1000  $\Omega$*
  - *Record electrical events every 30 seconds*
- **Intermittent Failure Definition**
  - *Component fails test level but passes subsequent level*
  - *Considered a failure at subsequent level*
  - *Captured components with intermittent failures*



# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I

### Equipment Set-up

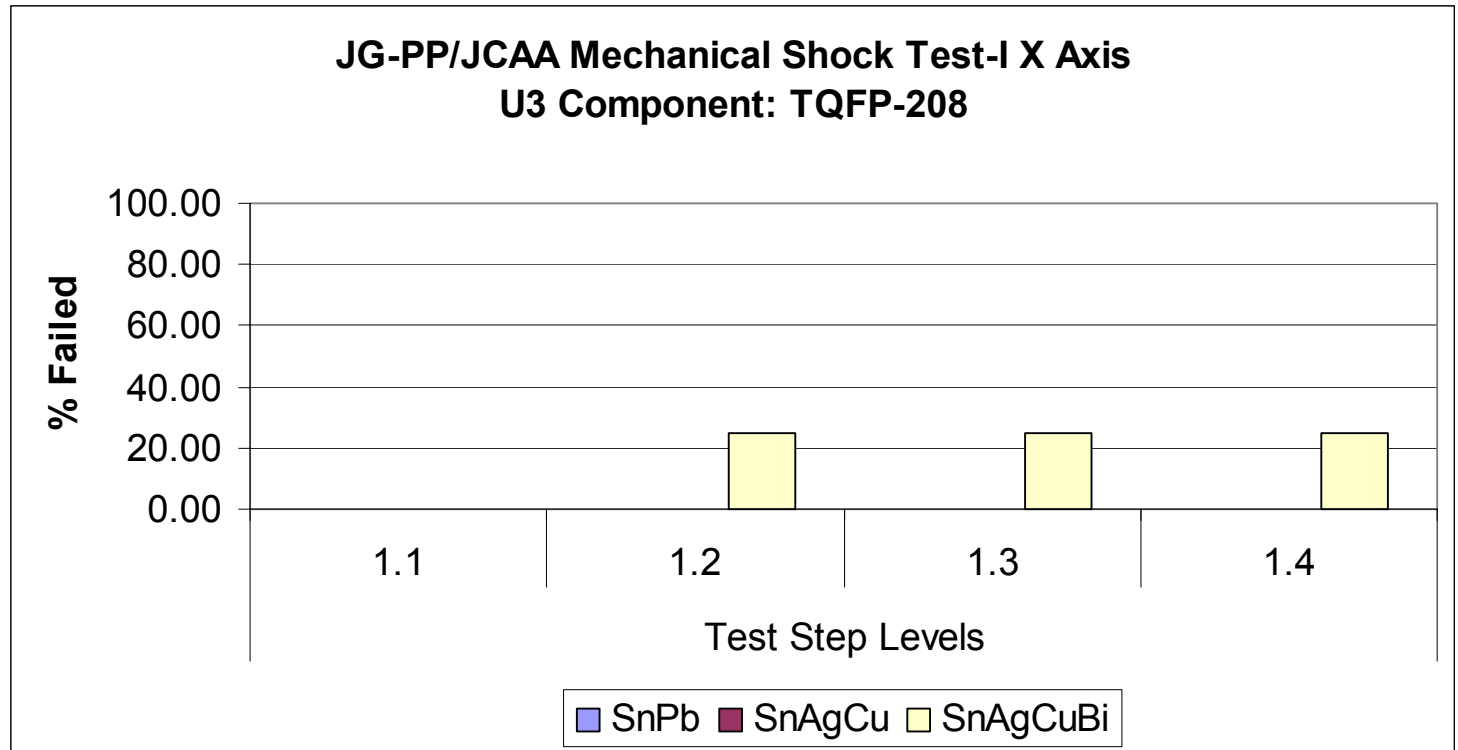


Ling Electronics B335 Vibration Systems  
Courtesy of BAE Systems, Lansdale, Pennsylvania



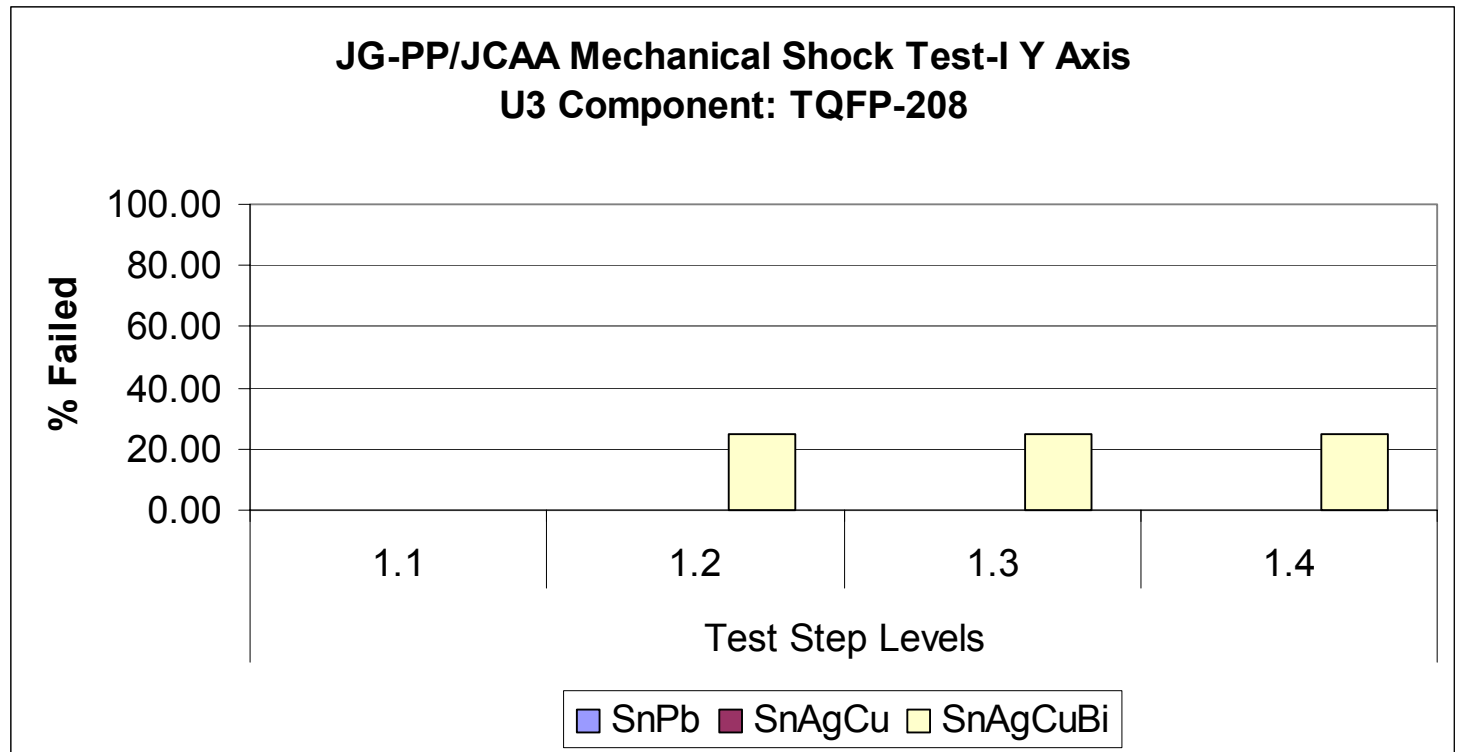
# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I Results



# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I Results

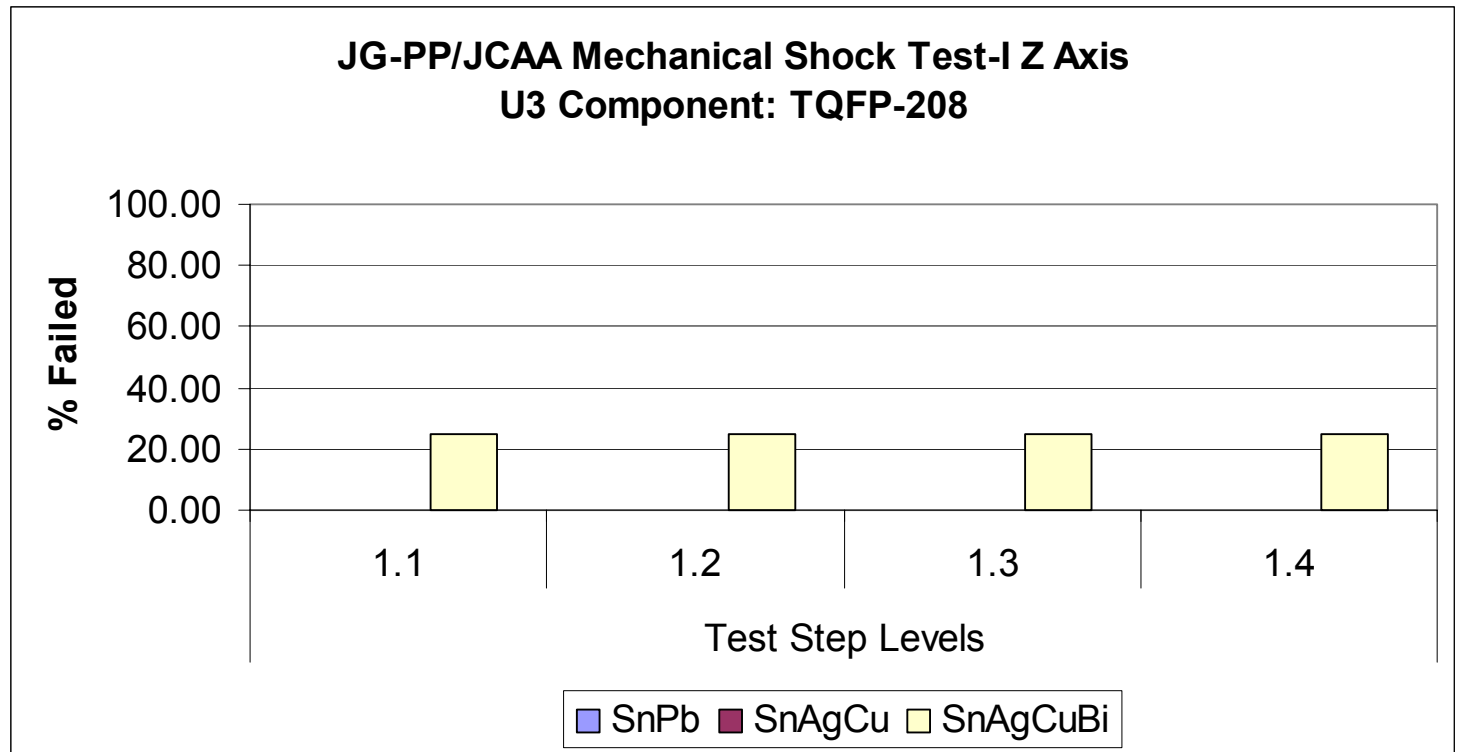


Intermittent Failures Found at Level 1.4



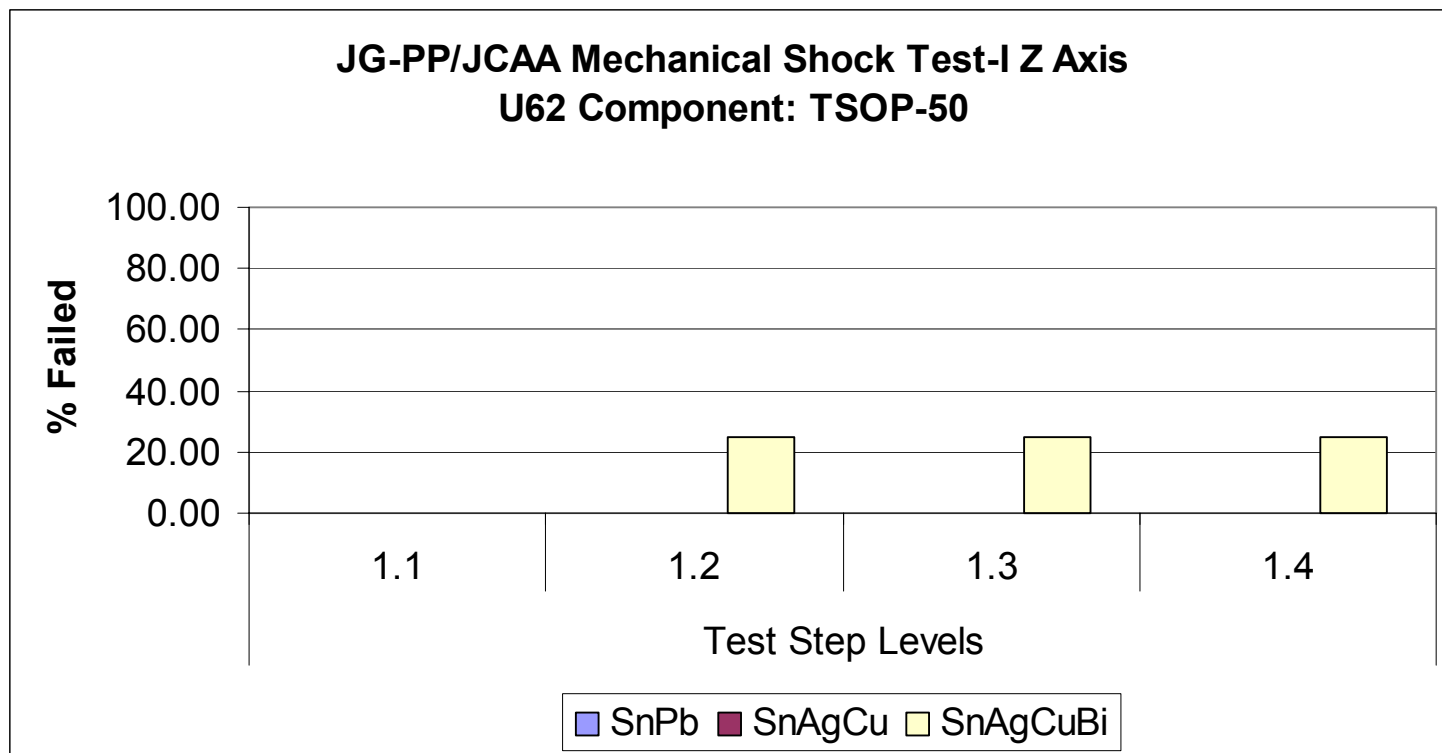
# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I Results



# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I Results





# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – I Conclusions

- **Test Results**

- *SnPb: No Failures*
- *SnAgCu: No Failures*
- *SnAgCuBi: Failures on all axis tested*
  - *TQFP-208: Component U3*
  - *TSOP-50: Component U62*

- **Conclusions**

- *SnPb and SnAgCu passed Mechanical Shock test*
- *SnAgCuBi: 4 failures detected*
  - *Component U3 continues to fail as in similar tests performed*
  - *Can be applied to other packages*



# JG-PP / JCAA Mechanical Shock Testing

## - Mechanical Shock Test – II

- **Mechanical Shock Test – II Test Procedure**
  - *Modified version of MIL-STD 810F; Method 516.5; Procedure 1*
  - *Hardware tested to failure in Z-Axis only*
  - *More Severe and Endurance type test*
- **Boards Tested**
  - *SnPb Boards: Serial Numbers 28, 29, 64, 65*
  - *SnAgCu Boards: Serial Numbers 97, 98, 170, 171*
  - *SnAgCuBi Boards: Serial Numbers 136, 137, 198, 199*



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

### Mechanical Shock – II Test Procedure

Step	Test	Initial G	Slope	Peak G	Ts (ms)	Cross-Over Freq.	Total Shock
2.1	Functional test for flight equipment	4.5	6	20	15-23	45	100
2.2	Functional test for Ground equipment	8.5	6	40	15-23	45	100
2.3	Crash Hazard test for flight equipment	9	6	75	8-13	80	100
2.4	Level 1	12	6	100	15-23	80*	100
2.5	Level 2	25	6	200	15-23	80*	100
2.6	Level 3	35	6	300	15-23	80*	100
2.7	Level 4	52	6	500	15-23	80*	100
2.8	Level 5	72	6	700	15-23	80*	100
2.9	Level 6	90	6	1000	15-23	80*	100

Hardware Tested To Failure In Z-axis Only



# JG-PP / JCAA Mechanical Shock Testing

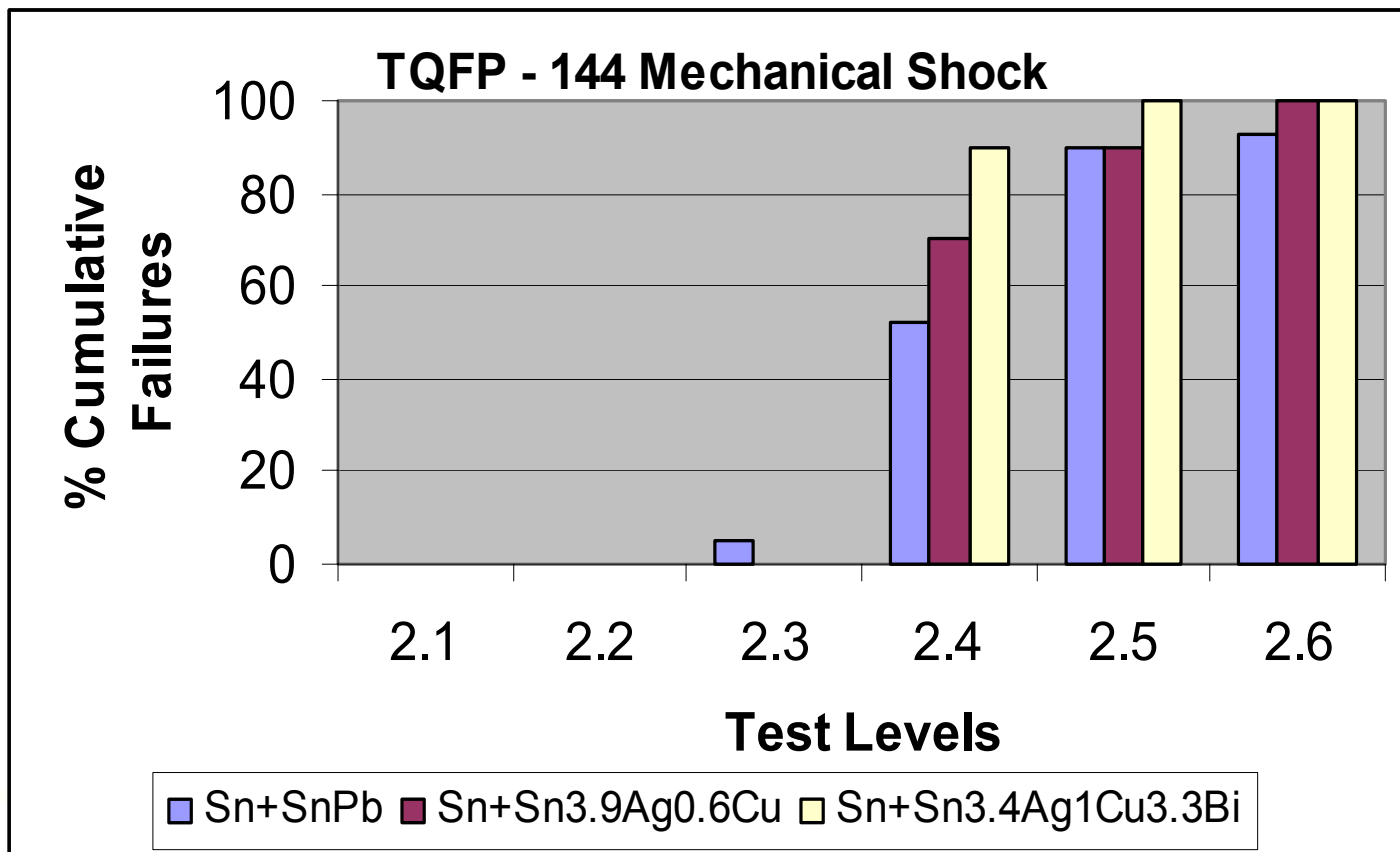
## Mechanical Shock Test – II

- **Continuity Testing**
  - *Performed before and after each round of tests*
  - *Confirmed failures from Event Detectors*
  - *Determine intermittent failures*
- **Hardware Monitoring: Anatech Event Detector**
  - *Continuous monitoring during testing*
  - *Detect electrical interruption lasting greater than 0.2  $\mu$ sec*
  - *Detect continuity interruption  $\geq 300 \Omega$  up to 1000  $\Omega$*
  - *Record electrical events every 30 seconds*
- **Intermittent Failure Definition**
  - *Component fails test level but passes subsequent level*
  - *Considered a failure at subsequent level*
  - *Captured components with intermittent failures*



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

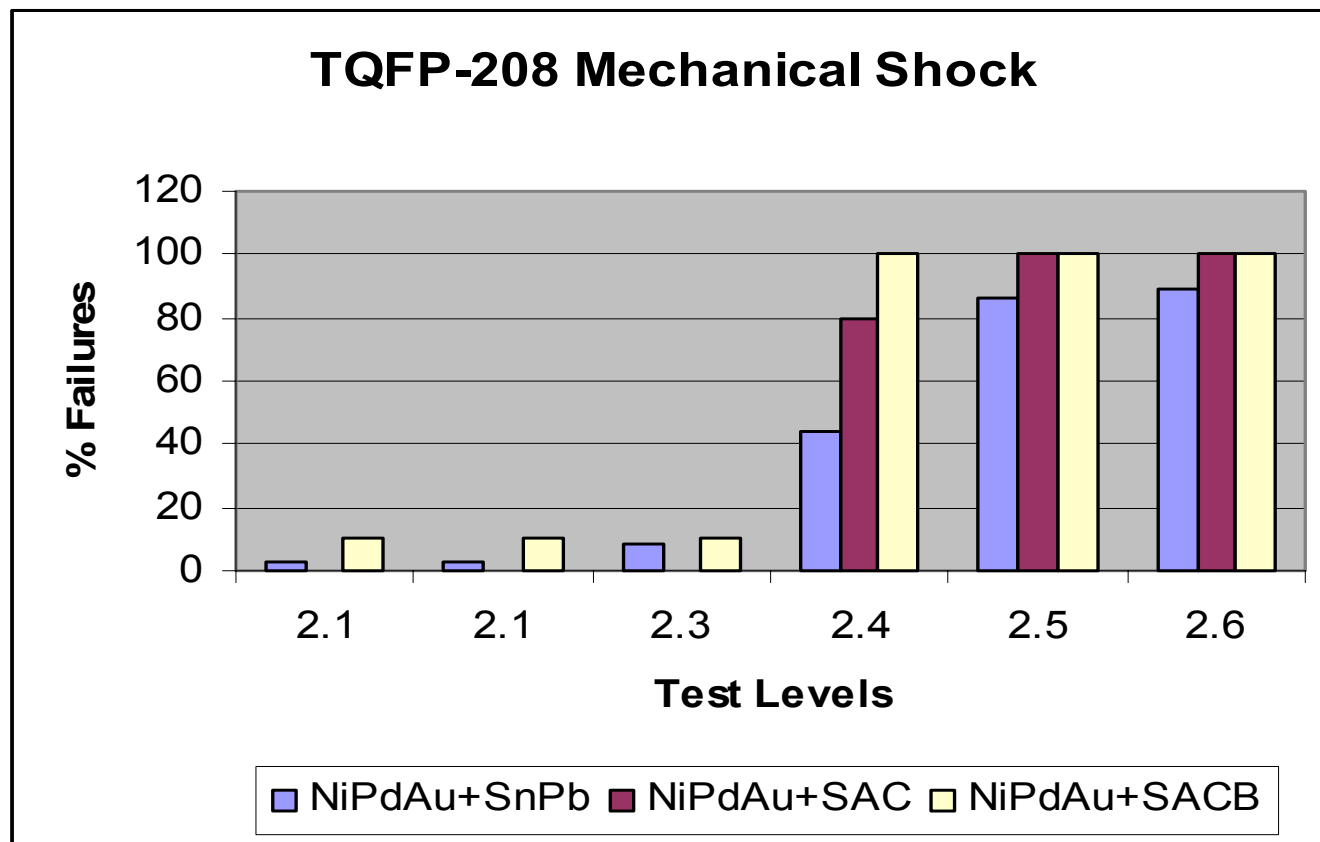


Intermittent SnPb Failures Found at Level 2.6 (40%)



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II



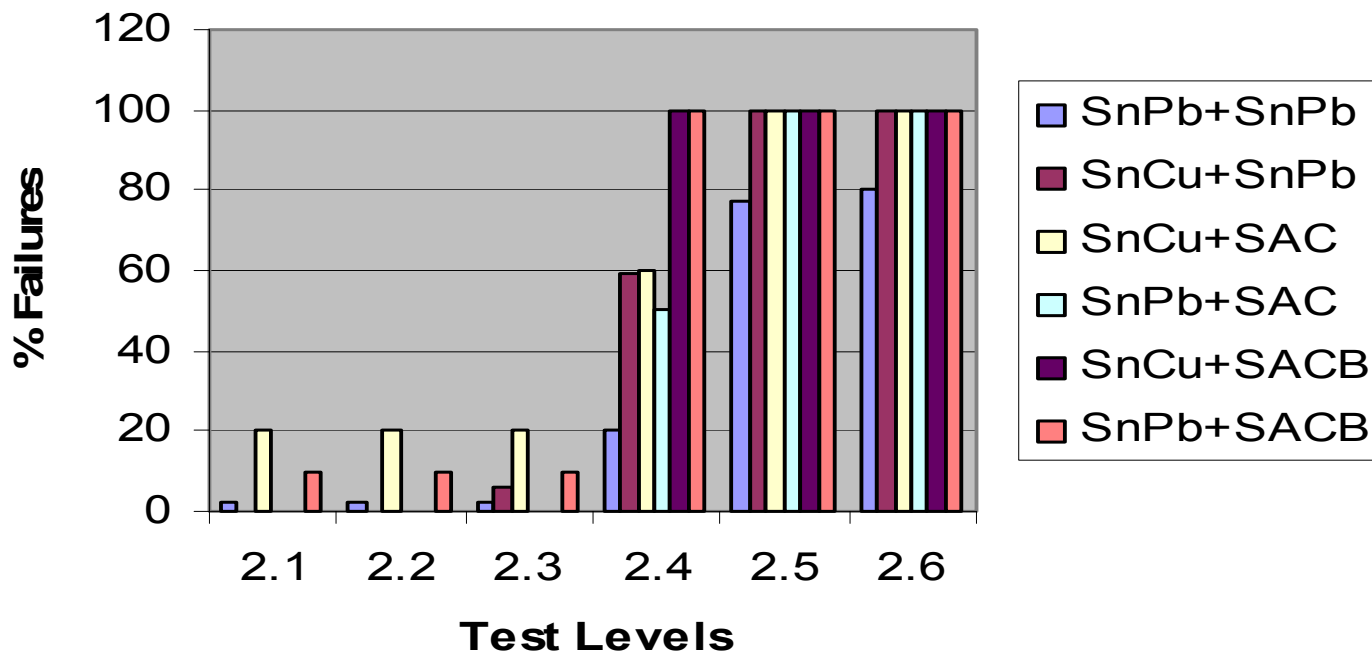
Intermittent SnPb Failures Found at Level 2.6 (52.5%)



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

### TSOP-50 Mechanical Shock



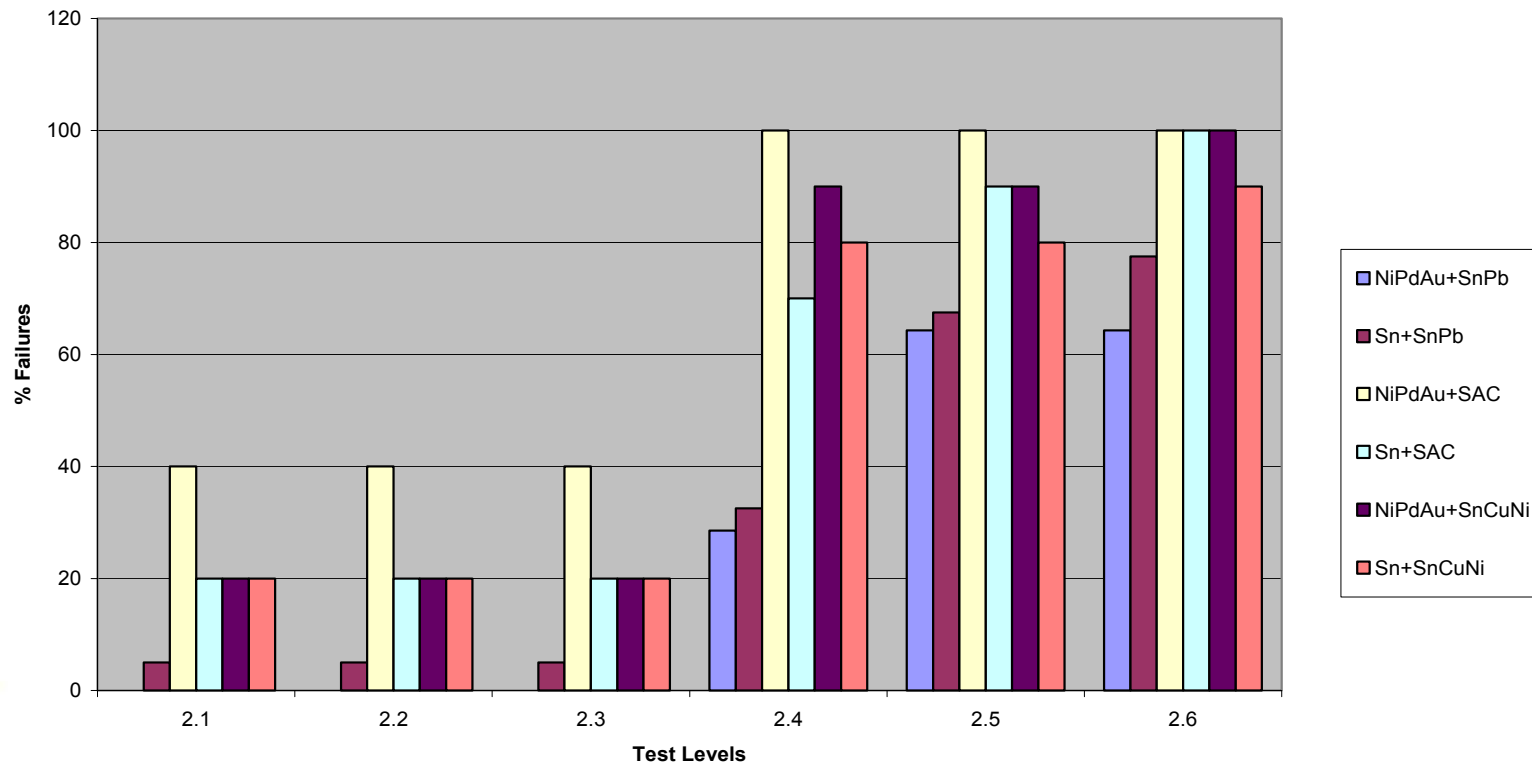
Intermittent SnPb Failures Found at Level 2.6 (50%)



# JG-PP / JCAA Mechanical Shock Testing

## PDIP-20 Mechanical Shock Test – II

Component PDIP-20 Failures

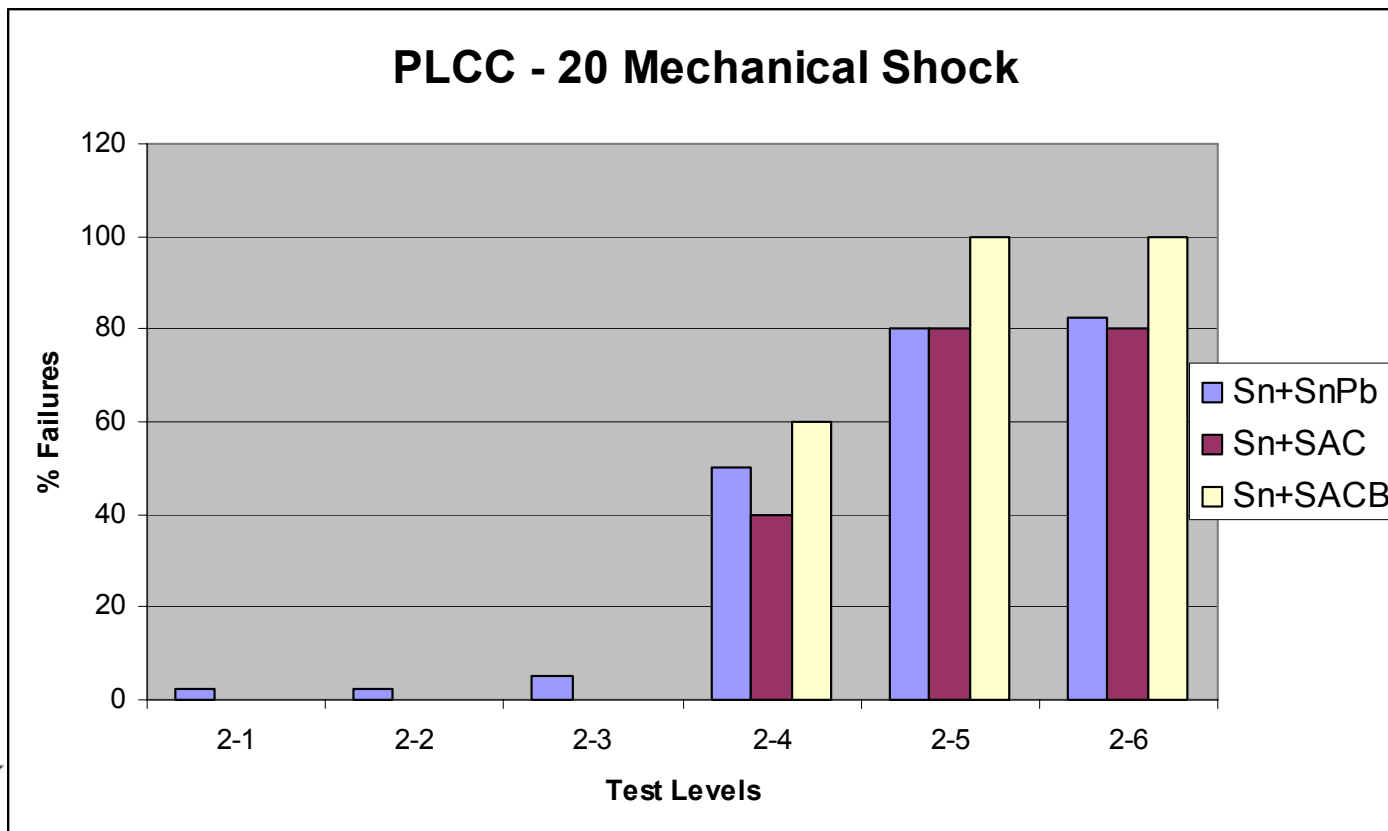


Intermittent SnPb Failures Found at Level 2.6 (52.5%)



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II



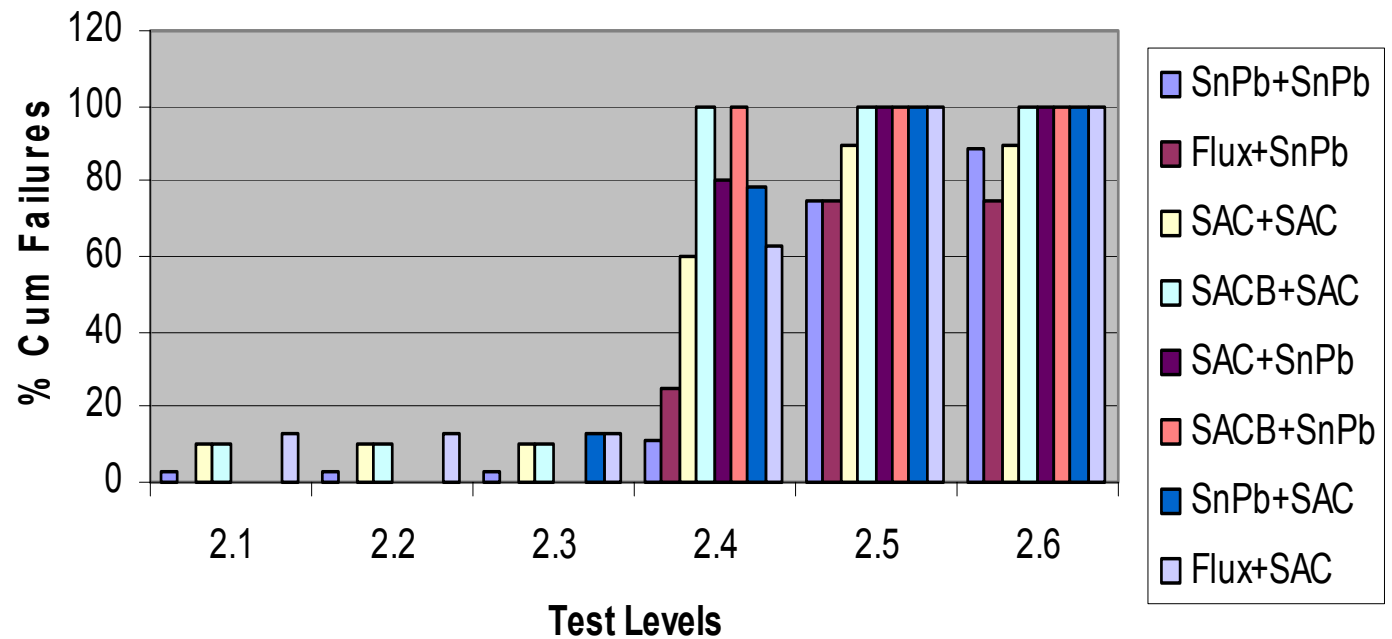
Intermittent SnPb Failures Found at Level 2.6 (35%)



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

BGA -225 Mechanical shock



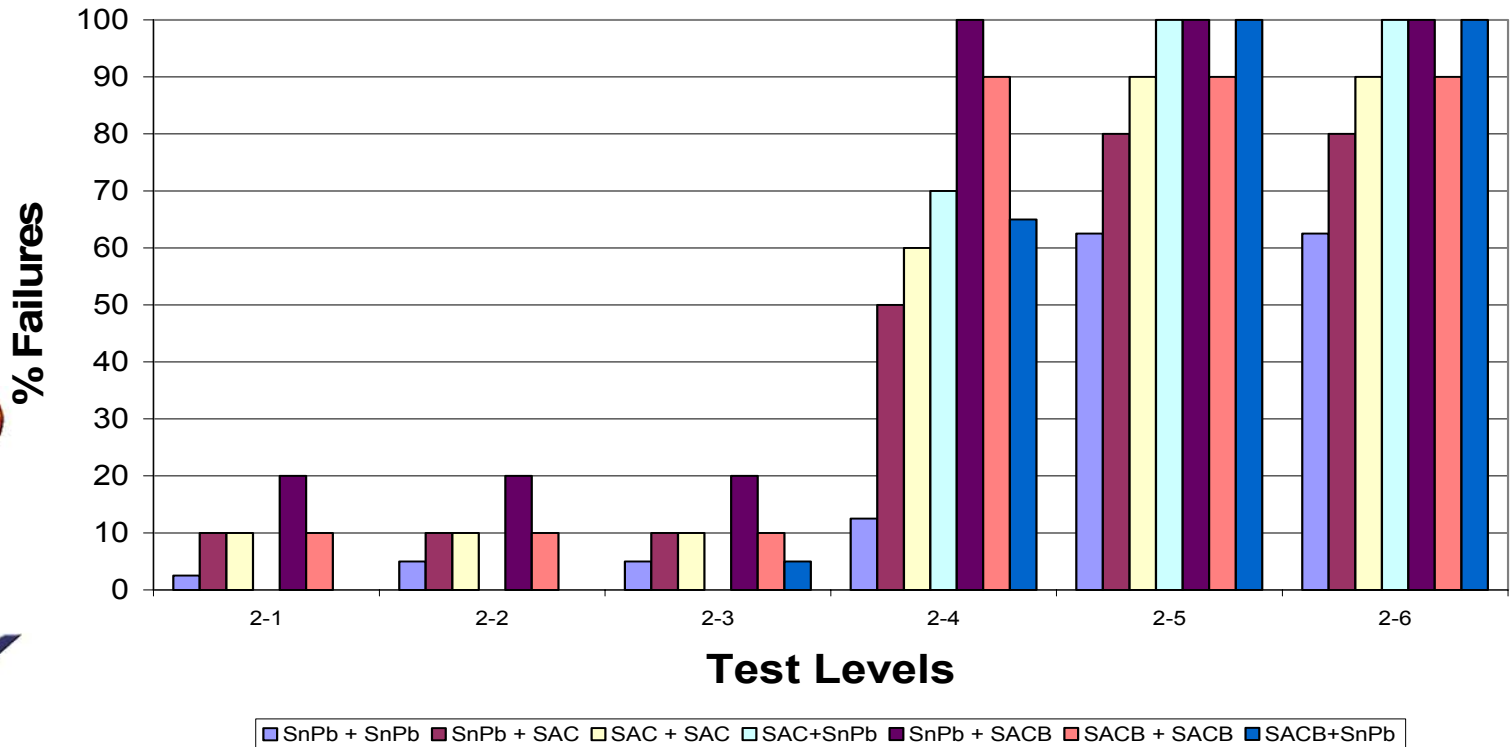
Intermittant SnPb failures 52%



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

### JCAA / JG-PP Mechanical Shock Test-II Component: CLCC-20



Intermittent SnPb Failures Found at Level 2.6 (45%)

# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II Conclusions

- **Initial Evaluation: Assuming Failures at the solder joints**
  - SnPb Performed Better Than SnAgCu and SnAgCuBi
  - *Lead Free Solder failures most prominent after Level 2.3*
- **Intermittent Failures**
  - *Intermittent Failure Definition*
    - *Component failed at one level, passes in subsequent level*
    - *Considered a failure*
    - *Kept track of individual component performance*
  - *SnPb had high levels of Intermittent Failures*
    - *~ 50% of all components tested had intermittent failures*
    - *Most prominent at Level 2.6*





# **JG-PP / JCAA Mechanical Shock Testing**

## **Mechanical Shock Test – II**

**FMA**

- One board from each solder type evaluated
  - Visual microscope
  - and X-ray inspection
  - Electrical probe testing does not pinpoint failure site
  - Dye-n-Pry
    - Microscope exam yielded solder joint surface cracks
  - Cross-section and SEM
    - Only for BGA devices

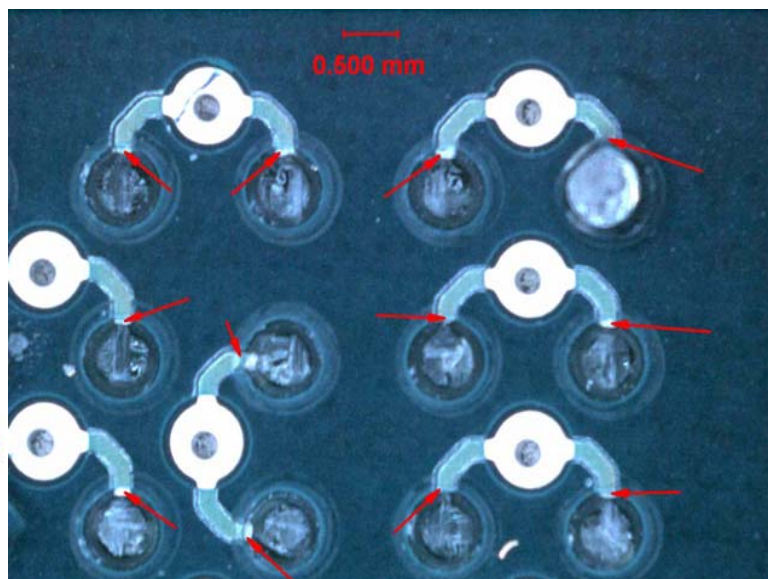


# JG-PP / JCAA Mechanical Shock Testing

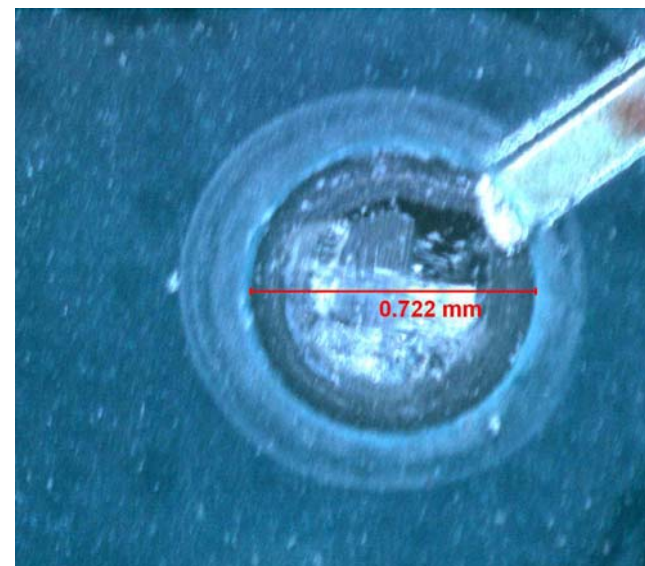
## Mechanical Shock Test – II

FMA

BGA -225 Failures



Top down view of board  
Top Right hand Corner Area of a BGA



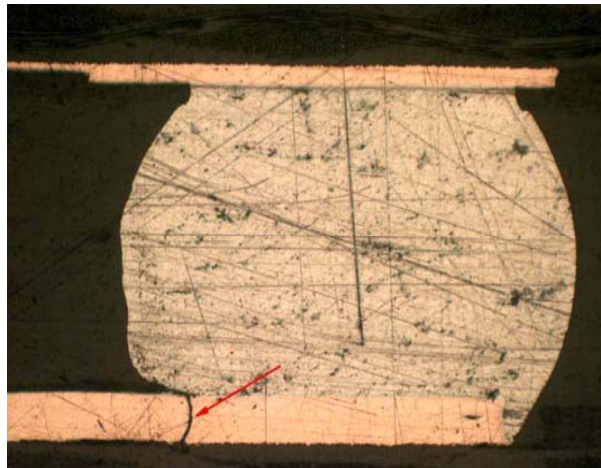
BGA Ball Solder Pad



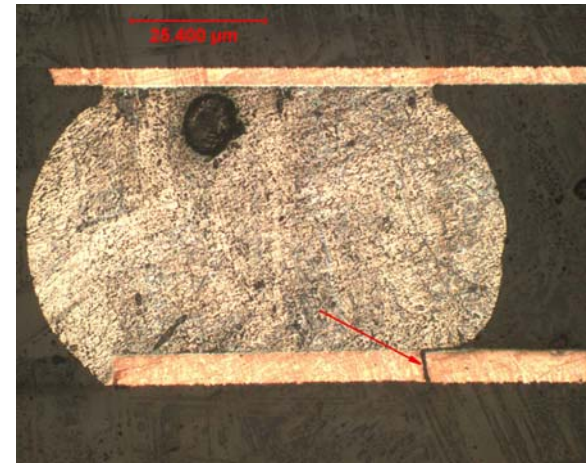
# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

FMA



SnPb MANUFACTURED, BGA U44, PCB trace failure at BGA Ball



SnAgCu/SnAgCu, BGA U44, PCB trace failure at BGA Ball

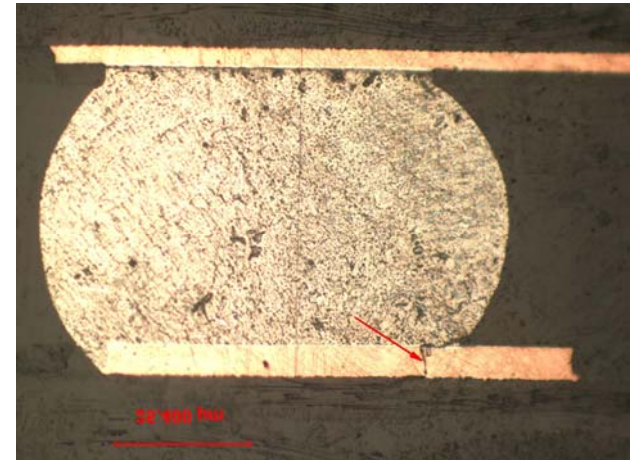
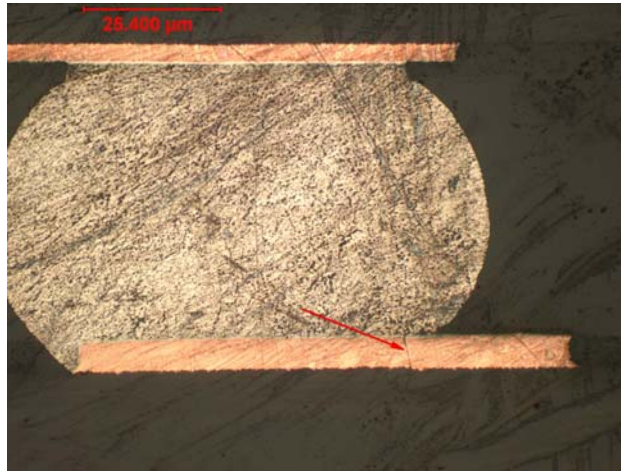




# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

FMA



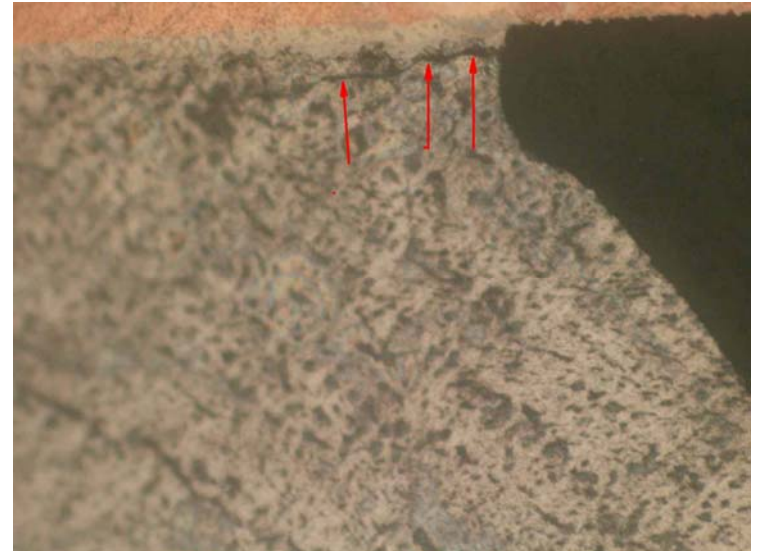
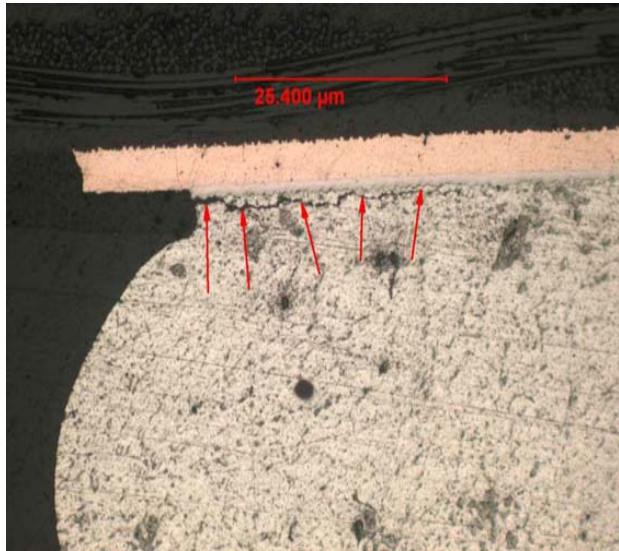
SnAgCu/SnAgCu, BGA U44,  
PCB trace failure at BGA Ball  
This type of failures could  
cause intermittent electrical  
failures



# JG-PP / JCAA Mechanical Shock Testing

## Mechanical Shock Test – II

FMA



SnPb MANUFACTURED, BGA U44,.

SnAgCu/SnAgCu, BGA

Solder Ball crack on the Component side, No failures of this type found but small amount of cracking seen

# JG-PP / JCAA ACI Environmental Testing

## - Conclusions

- **Salt Atmosphere Test: Found No failures**
  - *SnPb, SnAgCu and SnAgCuBi considered equivalent*
- **Temperature Humidity Test: Found No failures**
  - *SnPb, SnAgCu and SnAgCuBi considered equivalent*
- **Mechanical Shock Test - I**
  - *SnPb and SnAgCu passes test*
  - *SnAgCuBi had specific component failures (FMA needed)*
- **Mechanical Shock Test – II**
  - *Overall SnPb boards outperformed SnAgCu and SnAgCuBi*
  - *Detailed FMA is needed to provide solder comparison*
  - *Limited FMA on BGA devices indicate copper traces are primary cause of failure*



# JG-PP / JCAA ACI Environmental Testing

## - Acknowledgements

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